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Frequency effects in the written and spoken production of homophonic picture names

Patrick Bonin and Michel Fayol

LAPSCO/CNRS, Université Blaise Pascal (Clermont-Ferrand), France

In Experiment 1, participants had to write down or to speak aloud the names of either high frequency (HF) or low frequency (LF) heterographic homophonic picture targets. The most important finding was that HF targets took less time to initialise than LF targets in both spoken and written production. In Experiment 2, participants had to categorise the same picture targets as ''artificial'' or ''naturally occurring'' objects. LF homophonic targets were categorised faster than HF ones. The findings offer no support for the claim made by Jescheniak and Levelt (1994) that low frequency word homophones inherit a processing advantage from their higher frequency mates. The implications of the findings for interpretation of the locus of word frequency effects in language production are discussed.

Pictures with high frequency (HF) names are spoken aloud faster and more accurately than pictures with low frequency (LF) names.[1] The so-called frequency effect has often been reported in the literature on spoken language production (Humphreys, Riddoch, & Quinlan, 1988; Huttenlocher & Kubicek,

[1] Responses for pictures with early acquired labels are also produced faster than those for pictures with late acquired labels (e.g., Barry, Morrison, & Ellis, 1997; Carroll & White, 1973; Morrison, Chappell, & Ellis, 1997; Morrison, Ellis, & Quinlan, 1992). In studies of picture naming, it is not easy to disentangle effects of word frequency and age of acquisition (AoA) since the correlation between concreteness and AoA is even higher than the correlation between AoA and word frequency. Pictures have concrete names and this therefore restricts the AoA scope. The discussion about the AoA issue will be considered in the General Discussion. For the sake of clarity, throughout the paper, we will talk in terms of word frequency effects even though these may, in fact, be AoA effects (see General Discussion). However, it must be stressed that this aspect does not undermine the purpose of the present study since theoretical accounts of AoA and word frequency in word production are similar in terms of the models that are considered in the paper.

Requests for reprints should be addressed to P. Bonin, Laboratoire de Psychologie Sociale de la Cognition et Psychologie Cognitive (LAPSCO), Université Blaise Pascal, 34, avenue Carnot, 63037 Clermont-Ferrand, France. Email: Patrick.Bonin@srvpsy.univ-bpclermont.fr

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1983; Jescheniak & Levelt, 1994; Lachman, 1973; Lachman, Shaffer, & Henrikus, 1974; Oldfield & Wingfield, 1965) and it is the most widely reported effect in the field of visual word recognition (Forster & Chambers, 1973; Rayner, 1977). In contrast, studies of word frequency effects in written production in normals are very scarce (Bonin, Fayol, & Chalard, 2001; Bonin, Fayol, & Gombert, 1998).

THE LOCUS OF WORD FREQUENCY EFFECTS IN SPOKEN LANGUAGE PRODUCTION

There is general agreement among language production researchers that spoken production involves the following processing levels: conceptual preparation, lemma selection, lexeme retrieval, and articulation (Bock & Levelt, 1994; Levelt, 1989, 1999; Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992; but see Caramazza, 1997; Caramazza & Miozzo, 1997, for a different view).

Regarding the locus of word frequency effects in spoken production, most accounts have localised them at the level of phonological representations (Jescheniak & Levelt, 1994; La Heij, Puerta-Melguizo, van Oostrum, & Starreveld, 1999; Levelt et al., 1999; but see Barry et al., 1997; McCann & Besner, 1987; Wheeldon & Monsell, 1992). More precisely, Jescheniak and Levelt (1994) have proposed that frequency effects might be rooted at the level of phonological lexeme retrieval. The evidence favouring a phonological locus account of frequency effects in spoken production is as follows. In their extensive study of word frequency effects in speech production, Jescheniak and Levelt (1994) showed that frequency effects were not found in either an object recognition task (see also, Wingfield, 1967, 1968) or in a delayed word production task (see also Forster & Chambers, 1973). Because these tasks are assumed to index conceptual representations (Jescheniak & Levelt, 1994; Morrison et al., 1992) and articulatory components (Balota & Chumbley, 1985; Jescheniak & Levelt, 1994; Morrison et al., 1992) respectively, Jescheniak and Levelt (1994) concluded, by a process of elimination, that frequency effects were genuine lexical effects.

In their modelling of lexical access in spoken production, they acknowledged three possible loci for word frequency effects: the lemma level, the links between the lemmas and the lexemes, or the lexeme level itself. The main argument for localising frequency effects at the level of phonological lexemes rather than at the level of lemmas, or in the links between lemmas and lexemes, stemmed from an experiment in which participants had to speak aloud homographic homophones. According to Levelt et al. (1999), homophones differ at the conceptual level and at the lemma level while still sharing the same phonological representation. Take for example, the two words *boy* and *buoy*. *Boy* is a HF noun whereas *buoy* is a LF noun. According to Jescheniak and Levelt (1994), if word frequency is coded at the lemma level or in the links between lemmas and lexemes, *buoy* should be as difficult to access as a matched LF non-homophone word. However, if the frequency of the words is coded at the phonological lexeme level, a LF homophone, *buoy*, should be accessed just as quickly as its HF twin, *boy*, because both words share the same phonological form, /bɔi/. Jescheniak and Levelt (1994) used a translation task to test for these alternative hypotheses. Dutch participants with a good mastery of English were presented with the English translation equivalent of Dutch LF homophones. When presented with a word, they had to say aloud the Dutch translation. The same procedure was followed for HF and LF matched non-homophone controls. Because, in the translation task, the spoken latencies were also affected by the speed of recognition of the English word, the recognition speed was assessed by means of a semantic decision task. The most interesting aspect of the data was the difference scores, i.e., naming latency minus semantic decision latency. The important result was that LF homophones (*buoy*) were statistically as fast as the HF controls and faster than the LF frequency controls. Clearly, then, these findings showed that a LF homophone inherits the frequency of its HF twin.

To the best of our knowledge, Jescheniak and Levelt's (1994) study has provided the clearest evidence to date in support of a phonological lexeme locus of word frequency effects in speech production (for further evidence in support of this view, see also Stemberger & MacWhitney, 1986, for evidence from TOT states, and Dell, 1990, for evidence from errors). Following Levelt et al. (1999), the mechanisms that give rise to the emergence of frequency effects could be modelled in two different ways. One is to propose, as Jescheniak and Levelt (1994) have done, that frequency effects are due to different word form activation thresholds, or to different resting activation of word nodes (Dell, 1986; Stemberger, 1985). Another is to assume the existence of a frequency-sensitive verification mechanism, whose function is to licence each selection (Roelofs, 1997). The most important point here is that these accounts clearly share the key idea that frequency effects originate at the level of phonological representations.

Although there is widespread agreement among researchers in assuming that spoken production involves a level of lemma selection and of lexeme retrieval, Caramazza (1997) has recently argued that it is not necessary to postulate a modality-neutral level of lexical representations, i.e., the lemma level, located at the interface between semantic representations and modality-specific representations, i.e., the lexemes. In Caramazza's (1997) Independent Network Model (referred to as INM), lexical knowledge is organised in sets of independent networks connected to each other by modality-specific lexical nodes. The lexical-semantic network represents word meanings as sets of semantic features. The lexical-syntactic network represents a word's syntactic features such as its grammatical category and its gender. The phonological-lexeme and orthographic-lexeme networks consist of the modality-specific representations of lexical items. The INM postulates direct links between lexical-semantic representations and modality-specific (phonological and orthographic) lexical representations referred to as phonological and orthographic lexemes respectively. Thus, this model does not postulate an intermediate level of modality-neutral lexical representations (lemmas).

As far as homophones are concerned, according to Roelofs, Meyer, and Levelt (1998), one lexical layer models such as Caramazza's (1997; Caramazza & Miozzo, 1997) INM model, in which only the lexeme level is represented, require us to postulate the existence of separate phonological lexemes for any given pair of homophonic words. So, for instance, each of the homophones *buoy* and *boy* would have a separate phonological lexeme in the phonological output lexicon, with both of them being connected to a shared phonological segmental level. Frequency effects in spoken language production in the one lexical layer models might arise during the accessing of the lexeme nodes. Thus, the prediction is that LF homophones such as *buoy* should have a longer mean spoken naming latency than their HF twins, such as *boy*. However, this prediction is contradicted by the empirical evidence reported by Jescheniak and Levelt (1994).

Another way of accounting for word frequency effects in language production has been suggested by Wheeldon and Monsell (1992). With connectionist learning models in mind, Wheeldon and Monsell (1992) have viewed the long-lasting repetition effects in spoken production as grounds for proposing that word frequency effects should be ascribed to the links between semantic and phonological representations (see Barry et al., 1997; McCann & Besner, 1987, for a similar suggestion). Given this suggestion, the weightings associated with the links between semantic representations and HF homophonic names should be greater than those associated with the links between semantic representations and LF homophonic names.

WORD FREQUENCY IN WRITTEN PICTURE NAMING

As far as written production is concerned, we are not aware of any extensive study of word frequency effects in normal participants. Bonin, Fayol, and Gombert (1998) have shown that frequency effects in writing words from pictures are genuine lexical effects since they found no significant frequency effect either in a recognition task or in a delayed written picture naming task. The recognition task was the same as used by Jescheniak and Levelt (1994). Participants were presented with a word which was immediately followed by a picture. Their task was to decide as quickly as possible whether the word denoted the object in the picture and to press a yes or no button accordingly. In the delayed writing task, the participants were presented with pictures for 1500 ms and had to delay their written production until a cue (''?'') appeared after a variable delay of 1200, 1400, 1600, or 1800 ms.

Regarding the access to written name representations in written production, two hypotheses have been put forward. According to the obligatory phonological mediation hypothesis, access to phonological representations is a prerequisite for the derivation of orthographic codes (Geschwind, 1969; Luria, 1970), whereas according to the alternative hypothesis, the orthographic autonomy hypothesis, orthographic representations can be accessed directly on the basis of semantic specifications (Caramazza, 1997; Miceli, Benvegnu, Capasso, & Caramazza, 1997; Rapp, Benzing, & Caramazza, 1997; Rapp & Caramazza, 1997). The obligatory phonological mediation hypothesis has been seriously called into question by observations of brain-damaged patients who exhibited relatively well-preserved writing abilities despite severe impairments in speaking (Assal, Buttet, & Jolivet, 1981; Bub & Kertesz, 1982; Rapp & Caramazza, 1997; Shelton & Weinrich, 1997) and also by experiments involving normals (Bonin, Fayol, & Peereman, 1998). As far as word frequency effects are concerned, the phonological mediation hypothesis of written production holds that the locus of frequency effects should be the same as in spoken production, namely at the phonological lexeme level. Because this hypothesis has been severely criticised, it will not be considered further in the remainder of the paper. In contrast, according to the orthographic autonomy hypothesis, which claims that orthographic representations can be accessed directly from semantic specifications, the most likely locus of word frequency effects is the orthographic level, i.e., the orthographic lexeme level.

The purpose of our study was to further investigate word frequency effects in spoken and written production using heterographic homophonic picture names. In contrast to Jescheniak and Levelt (1994), who used a translation task, we employed a standard picture naming task. Pairs of heterographic homophonic picture names that varied on their frequency in print were selected. For each pair of homophones, one member appeared more frequently in print than its partner. We distinguished between two sets of homophones on the basis of their *relative* frequency in print. One set corresponded to the high frequency members and the other set to the low frequency members. For the sake of simplicity, these two sets are referred to as ‘‘HF homophones’’ and ‘‘LF homophones’’ respectively. Each pair of homophonic names was unrelated in meaning. For instance, *verre* (meaning glass) and *ver* (meaning worm) are heterographic homophones in French, since both are pronounced /vɛr/. However, they differ in their frequency in print with the written form *verre* being more frequent than the written form *ver*.

In the first experiment, participants had either to speak aloud or to write down homophonic names from pictures. Furthermore, they saw only LF homophone targets or HF homophone targets. We used a between-subjects design to present the two categories of homophones because the presentation of both members of a pair of homophones might have led to the use of anticipatory strategies. For instance, after having produced the LF homophone *ver*, participants might have anticipated the presentation of the HF twin *verre* and gone some way to preparing its production (or vice versa).

According to the phonological lexemic hypothesis of word frequency effects in spoken production as put forward by Jescheniak and Levelt (1994), because LF homophones inherit the frequency of their HF twins, we should find that the spoken naming speed is (statistically) as fast for a LF homophone (*ver*) as for its HF twin (*verre*). In contrast, according to models that postulate only one lexical layer, because there are separate phonological lexemes for HF and LF homophones, one should find that HF homophones are produced faster than their LF counterparts. The same prediction can be derived from the hypothesis that word frequency effects are encoded in the links relating semantic representations to phonological lexeme representations. As far as written production is concerned, if the orthographic autonomy hypothesis is adopted, we should find that a HF homophone is named faster than its LF twin. Note that this latter prediction is perfectly in line with Caramazza's (1997) view and also holds if we consider the hypothesis that word frequency effects are encoded in the links between semantic representations and orthographic representations. Finally, we were also interested in determining whether ''homophone frequency'' effects are robust in the sense that they are preserved over repeated namings of the same pictures, as Jescheniak and Levelt (1994) and, more recently, Levelt, Praamstra, Meyer, Helenius, and Salmelin (1998) have shown. Therefore, the pictures were presented four times in separate blocks for both language production tasks.

EXPERIMENT 1

Method

Participants. Fifty-two psychology students from Blaise Pascal University (Clermont-Ferrand) were involved in the experiment: Half completed the written production task and the remaining half the spoken production task. All were native speakers of French and had normal or corrected-to-normal vision.

Stimuli. The stimuli consisted of 36 black-on-white drawings. Some were taken from various children's picture books and some were drawn by an artist. The picture names corresponded to pairs of heterographic homophones. We distinguished between two sets of homophones: One set corresponded to the members whose frequency in print (the frequency values were taken from Imbs, 1971) was higher than their partners and, conversely, the other set corresponded to the members whose frequency was lower than their partners. As previously stated, the first set is referred to as HF homophones and the second set as LF homophones. For example, the pair *verre* (meaning glass) and *ver* (meaning worm) are heterographic homophones. One member (*verre*) is more frequent (in print) than the other member (*ver*). Therefore, *verre* was placed in the category of HF homophones and *ver* in that of LF homophones. The frequency contrast between the two sets of homophones was significant (see Table 1). As can be seen from Table 1, the two types of homophonic names were matched on number of letters, number of phonemes, bigram frequency, sound-to-print, and print-to-sound consistency. The bigram frequency values were taken from Content and Radeau (1988) and the consistency scores from Peereman and Content (1999). The mean statistical characteristics corresponding to these variables are presented in Table 1. The picture names are listed in the Appendix.

Apparatus. The experiment was performed with PsyScope, version 1.2 (Cohen, MacWhinney, Flatt, & Provost, 1993) and run on a Macintosh computer. The computer controlled the presentation of the pictures and recorded the latencies. A graphic tablet (WACOM UltraPad A5) and a contact pen (UP 401) were used to record the graphic latencies. The spoken latencies were recorded with the Button-Box connected to the computer and an AIWA CM-T6 small tie-pin microphone connected to the Button-Box.

Procedure. The participants were tested individually. They were randomly assigned to either the written production task or to the spoken production task. They were also presented with either HF homophones or LF homophones.

During a preliminary phase, they had to learn to associate the name corresponding to each picture correctly. To this end, each picture was presented on

TABLE 1
Characteristics of the homophone targets used in Experiments 1 and 2

	HF homophones	*LF homophones*	*p values*
Frequency*	18346 (3.91)	2025 (2.77)	<.05 (<.01)
Nb. of letters	4.39	4.44	n.s.
Nb. of phonemes	2.94	2.94	n.s.
Bigram frequency**	1771	1862	n.s.
PO onset (C1) consistency***	0.87	0.82	n.s.
PO vowel (V) consistency***	0.65	0.62	n.s.
PO coda (C2) consistency***	0.41	0.44	n.s.
PO–CV***	0.68	0.64	n.s.
PO–VC***	0.27	0.20	n.s.
OP–C1***	0.88	0.84	n.s.
OP–V***	0.91	0.93	n.s.
OP–C2***	0.93	0.88	n.s.
OP–CV***	0.98	0.98	n.s.
OP–VC***	1.00	0.93	n.s.

Nb = number; PO = phonology-to-orthographyconsistency; OP = orthography-to-phonology consistency; * Frequency per 100 million from Imbs (1971) (log frequency in parentheses); ** from Content and Radeau (1988), values by type; *** values by type as given by LEXOP (Peereman & Content, 1999).

the screen with its name written below it while also being auditorily presented via headphones (Sennheiser HD 25 SP). The picture remained on the screen until the participant pressed the space bar. The participants were told to look carefully at each picture, to learn its name and then, when they felt they knew its name, to press the key to proceed to the next picture. Each learning trial had the following structure: A ready signal (''*'') was presented for 1000 ms and followed 200 ms later by the picture. The written name of the picture and its spoken name were presented 50 ms after picture onset. When the participant pressed the key, the next trial began after a delay of 1000 ms. The time taken to learn the association between the name and the picture was recorded. To ensure that the participants had correctly learned the names associated with the pictures, the experimenter tested them on all pictures.

The rationale for conducting this learning phase was that our production experiments required the selection of specific measurable responses, and in production there is often no easy way to obtain specific responses (Bock, 1996). In cases where the name corresponding to each picture is not stipulated, the problem is that something other than the target is very often produced with the consequence that many of the responses must be discarded because of their uncertain bearing on the questions of interest. Thus, ''specified elicitation'' is frequently used in spoken picture naming studies in order to reduce variability in the names used to refer to the pictures (e.g., Jescheniak & Levelt, 1994; Schriefers, Meyer, & Levelt, 1990; Starreveld & La Heij, 1995). The assumption is that the same lexical mechanisms are mobilised regardless of whether the desired response is spontaneous or specified in advance (Bock, 1996).

The second phase was the experimental phase. The participants were told that they would see a picture (presented on the screen at a viewing distance of about 60 cm) and, depending on the production mode, they quickly had to say aloud or write down the name corresponding to the picture. The experimenter monitored the participants' responses and scored them for correctness. The entire session lasted about half an hour.

A trial consisted of the following sequence of events: A ready signal (''*'') was presented for 500 ms followed by a picture. The picture remained on the screen until the participants initiated the spoken or the written response. The next trial began 5000 ms after the participants had initiated their response. This intertrial delay was established on the basis of studies similar to our own (Bonin & Fayol, 2000; Bonin, Fayol, & Gombert, 1997, 1998). For both output modes, the latencies were measured from picture onset to the initiation of the response.

Participants had either to write down or to speak aloud the names of the pictures depending on the group. They were also subjected to either HF or to LF homophones. Thus, there were four groups of participants. In each group, the homophones (HF or LF depending on the group) were randomly presented within a block. This block presentation was repeated four times, with a different randomisation each time. Therefore, each of the HF or the LF homophones, depending on the group of participants, was produced four times in separate blocks with a short break between each block.

The written responses were timed as follows: The participants sat with the stylus right above the tablet so that the latency was the time taken to make contact after picture onset. The timing was accurate to the nearest millisecond. In order to avoid any variability in the positioning of the stylus before each word was written, a line was drawn and the participant was obliged to position the stylus at the very start of the line at a height from the tablet which just touched the edge of the line. The experimenter systematically ensured that the instructions were adhered to and always corrected the participants if they failed to observe them.

Results

For both production modes, observations were discarded from the latency analyses in the following cases: The participant did not remember the picture name; a technical problem occurred; an item other than the expected one was produced. For the spoken responses, observations were also scored as errors when participants stuttered or produced non-linguistic sounds (such as mouth clicks) or repaired the utterance after a dysfluency. For the written responses, observations were discarded when a word was misspelled. Moreover, for both output modes, latencies exceeding two standard deviations above the participant and item means were discarded (1.66% of the data in the written production task and 1.55% in the spoken production task). Overall, 128 (6.8%) and 151 (8.0%) observations were discarded from the latency analyses in the spoken and written production task respectively.

Latencies and errors were subjected to ANOVAs with homophone frequency, production mode, and repetition as experimental factors. To generalise over both participants and items, ANOVAs were carried out on the participant means ($F1$) and on the item means ($F2$). Throughout the analyses, the conventional level of .05 for statistical significance was adopted.

The mean latencies and the error rates as a function of homophone frequency, repetition, and production mode are depicted in Figures 1 (speaking) and 2 (writing).

Error rates. There were more errors on LF homophones than on HF ones, $F_1(1, 48) = 20.06$, $MSe = 0.0127$; $F_2(1, 34) = 9.33$, $MSe = 0.0378$. The error rate decreased significantly with repetition of the picture names, $F_1(3, 144) = 3.05$, $MSe = 0.00250$; $F_2(3, 102) = 3.84$, $MSe = 0.00275$. The interaction between homophone frequency and repetition was significant on items, $F_2(3, 102) = 2.82$, but was only marginally significant on participants, $F_1(3, 144) = 2.24$. On item means, this interaction indicates that the difference in error rates between LF and HF words was larger in the first block than in the remaining blocks. No other main effect or interaction reached significance.

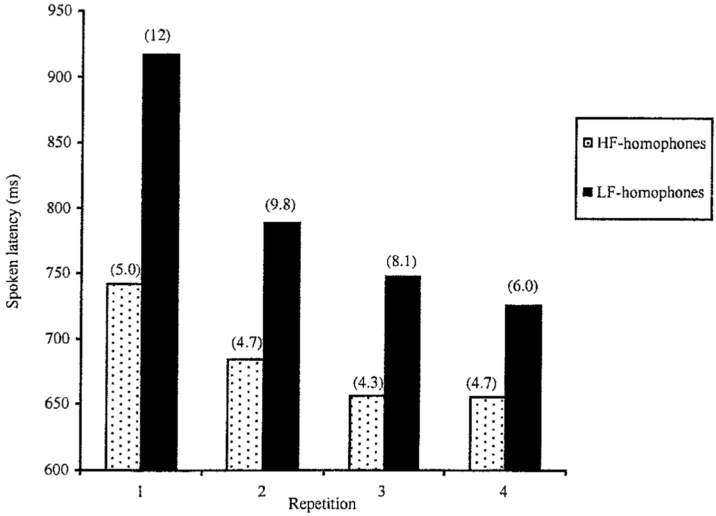

Figure 1. Mean spoken latencies (in ms) and percentages of errors (in parentheses) as a function of homophone frequency (HF homophones, LF homophones) and repetition (1, 2, 3, 4).

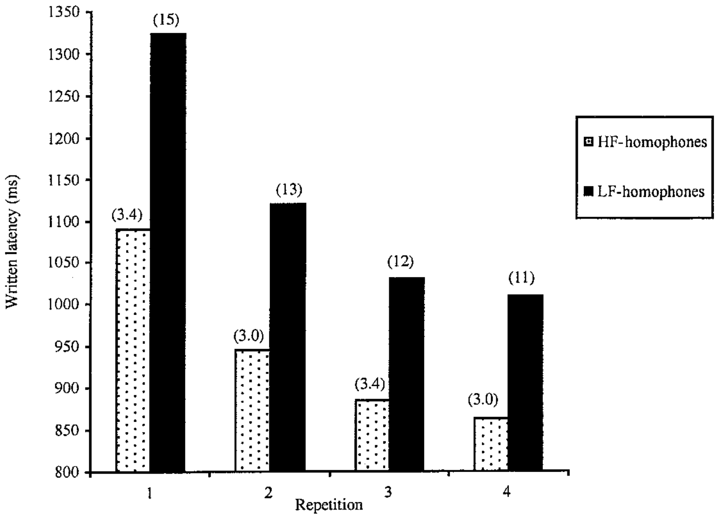

Figure 2. Mean written latencies (in ms) and percentages of errors (in parentheses) as a function of homophone frequency (HF homophones, LF homophones) and repetition (1, 2, 3, 4).

Latencies. The written latencies were longer than the spoken latencies, $F_1(1,48) = 103.04$, $MSe = 43{,}373$; $F_2(1,34) = 843.27$, $MSe = 7041$. HF homophones were named faster than LF ones, $F_1(1,48) = 24.16$, $MSe = 43{,}373$; $F_2(1,34) = 68.22$, $MSe = 21{,}556$. Also, the latencies decreased with repetition, $F_1(3,144) = 115.81$, $MSe = 3863$; $F_2(3,102) = 161.37$, $MSe = 3922$. There was a significant interaction between production mode and repetition, $F_1(3,144) = 12$, $MSe = 3863$; $F_2(3,102) = 24.55$, $MSe = 2397$. As can be seen from Figures 1 and 2, repeated presentation of the pictures for naming had a more beneficial effect on written production than spoken production. Planned comparisons revealed that the repetition effect was more important in writing than in speaking across presentations 1 and 2, presentations 2 and 3, but not across presentations 3 and 4. Also, homophone frequency interacted significantly with repetition, $F_1(3,144) = 6.25$, $MSe = 3863$; $F_2(3,102) = 8.72$, $MSe = 3922$. Planned comparisons indicated that the homophone frequency effect was greater in presentation 1 than in presentation 2, although remaining fairly constant across the remaining presentations. The interaction between homophone frequency and production mode was significant on the analyses by items only, $F_1(1,48) = 1.24$; $F_2(1,34) = 8.66$, $MSe = 7041$. On item means, this interaction indicates that the homophone frequency effect was larger in writing than in speaking. The three-way interaction was not significant ($Fs < 1$). Planned comparisons indicated that the homophone frequency effect was significant for both naming and writing on each presentation of the pictures. It is important to stress that the pattern of results was the same when only those pairs of homophones were analysed that allowed us to establish not a relative but an absolute frequency contrast.

Finally, the correlation between the spoken and written naming latencies on the item means was high (.78) and reliable ($p < .001$).

Learning times. The time taken to associate a picture with its name was longer for LF homophones than for HF ones (2.9 vs 3.3 s). The difference was significant on items, $F_2(1,34) = 13.11$, $MSe = 173{,}055$, but not on participants, $F_1(1,50) = 1.20$. Because of the reliable difference in the learning times on the items, an analysis was performed on the latency data with the learning times taken as a covariate. This analysis revealed that the pattern of results on the naming data remained the same.

Discussion

The main findings resulting from Experiment 1 were as follows. Homophone frequency effects were observed in spoken as well as in written production. The repeated presentation of the pictures had a more beneficial effect on written than on spoken performance. This latter finding is not surprising given that speaking is more often practised than writing, and written latencies were slower than spoken naming latencies, and thus had more room for improvement. Thus, the prior written production of the picture names is more beneficial to a subsequent writing sequence than is the case for spoken production. Furthermore, repetition interacted significantly with homophone frequency in such a way that the homophone frequency effect was greater for the first presentation of the pictures than for the three subsequent presentations. The attenuation of the frequency effect with repetition runs counter to the findings of Jescheniak and Levelt (1994) who found that the frequency effect did not change reliably over three presentations. However, this finding is consistent with other studies that showed that the frequency effect decreases with repeated presentations of the same set of pictures (e.g., Bartram, 1973; Griffin & Bock, 1998; Monsell, Matthews, & Miller, 1992; van Berkum, 1997; Wheeldon & Monsell, 1992).

Given the evidence for the phonological lexemic hypothesis of word frequency effects in spoken production reported by Jescheniak and Levelt (1994), the finding of a reliable homophone frequency effect in spoken production is rather surprising. Although a homophone frequency effect is clearly expected in written production if the orthographic autonomy hypothesis is adopted, in spoken production the Jescheniak and Levelt's (1994) results very much led us to expect that LF homophones would be produced as fast as HF homophones. However, we found that HF homophonic names were spoken aloud significantly faster than LF homophonic names. The latter finding is clearly at variance with those reported by Jescheniak and Levelt (1994) in their translation task, but it fits in well with an account that localises frequency effects in the links between semantic and phonological representations (McCann & Besner, 1987; Wheeldon & Monsell, 1992), or with an account that postulates separate phonological lexemes for homophones. However, before discussing further the implications of these findings (see the General Discussion), two points must be addressed.

A first point of concern is that the pictures were not matched on name agreement. It is noteworthy that this variable was not taken into account in the Jescheniak and Levelt (1994) study. Name agreement refers to the degree to which participants agree on the name of the picture. It is measured by taking into account the number of alternative names given to a particular picture across participants. Precisely, two measures of name agreement are generally computed: (1) the percentage of participants producing the most common name and (2) the statistic H (taken from Snodgrass & Vanderwart, 1980). According to Snodgrass and Vanderwart (1980), the H value captures more information about the distribution of names across participants than does the percentage agreement measure.

Name agreement has been found to have an independent effect on naming times (e.g., Barry et al., 1997; Ellis & Morrison, 1998; Snodgrass & Yuditsky, 1996). Thus, it might be argued that the name agreement of some of the LF homophones was so weak that we had, as a result of the preliminary training phase, induced the participants to artificially produce specific picture names for some of the items. If this were indeed the case then the frequency effect would be a simple ‘‘learning effect’’ since it would be easier for the participants to learn the appropriate HF names than the LF names. However, this interpretation is unlikely for the following reasons. First of all, although the learning times were indeed longer for LF homophones than for HF ones, we have already noted that the pattern of results was the same with the learning times taken as covariates. Also, when only a subset of pairs of HF and LF homophones matched on the learning times were considered, the pattern of robust effects previously described on the naming times was still found. Second, we asked two independent groups of participants (20 in each group) to either give the first bare noun that came to their mind when presented with each of the pictures (a name agreement task) or to indicate on a 5-point scale their degree of agreement on the name used to refer to each picture (a ‘‘name–picture’’ agreement task). As far as the name agreement task is considered, we found that, although both measures of name agreement (the percentage of agreement and the H value) indicated that HF homophones had a higher name agreement than LF homophones (82% vs 68% and 0.70 vs 1.05 for HF and LF homophones respectively), the difference was marginally significant on the percentage agreement measure ($p < .07$) and not significant on the H measure ($p = .16$). Because a trend was found on the percentage agreement measure, further analyses were performed on the naming latencies with the percentage agreement—and also with the H measures—taken as covariates. These analyses did not alter the pattern of results found on the naming data. Also, when only a subset of pairs of HF and LF homophones matched on either the percentage of agreement or on the H measure were considered, the same robust effects obtained with the entire set of items were again observed (the only exception was that the Homophone frequency × Repetition interaction effect was only marginally significant when the percentage of agreement measure was used). Also importantly, in all these analyses the homophone frequency effect was reliable for each presentation of the pictures. Finally, regarding the name–picture agreement task, we found that the degree of agreement was high and did not significantly differ between HF and LF homophones (4.38 and 4.18 respectively), $F_2(1, 34) = 1.26$. This set of analyses therefore allows us to reject an interpretation of the findings in terms of a learning effect.

A second point is related to the source of the word frequency effects we found. It is possible that the homophone frequency effects observed in Experiment 1 might be due to factors other than those that are supposedly related to lexicalisation processes. However, it is not difficult to reject a post-lexical interpretation of these effects. In effect, it cannot be the case that, in spoken production, the differences in initial phonemes had a differential effect in triggering the voice key since the two members of the homophonic pairs are spoken the same. They are therefore necessarily matched for initial phonemes. Also in written production, differences in initial letters cannot exert a differential effect on the triggering of the contact pen because, in all except three cases (*ancre–encre*, *signe–cygne*, *cent–sang*), the two members of the homophonic pairs shared the same initial letter, and moreover, when these items were discarded from the analyses, the pattern of results remained the same. More importantly, the differences in naming speed observed between HF and LF homophones might be attributable to difficulties in identifying the pictures and/or the familiarity of their meanings, i.e., conceptual familiarity. Therefore, to determine whether the differences between the two categories of homophones truly relate to lexicalisation processes and not to identification and/or conceptual processes, a semantic categorisation task was used in Experiment 2. The rationale was that if the effects associated with the two categories of homophones found in Experiment 1 are thought to arise at identification/conceptual levels, they should manifest themselves in a task that requires identification of the pictures, conceptual activation, but no overt language production, i.e., a semantic categorisation task. In Experiment 2, participants had to decide as quickly as possible whether the concept denoted by the picture referred to an ''artificial'' or a ''naturally occurring'' object. The choice of this specific semantic categorisation task was motivated by Morrison et al.'s (1992) study. If what has been referred to as the ''homophone frequency effects'', observed in Experiment 1, are attributable to identification/conceptual levels, we should find that LF homophones take longer to categorise than HF ones.

EXPERIMENT 2

Method

Participants. Thirty-two adults taken from the same pool as in Experiment 1 were recruited for this experiment. None had participated in Experiment 1.

Stimuli. The stimuli were the same as in Experiment 1. However, to ensure an equal number of ''artificial'' and ''naturally occurring'' items in the two categories of homophones, eight homophonic filler items were added.

Apparatus. A Macintosh computer controlled the presentation of the pictures and recorded the RTs.

Procedure. The procedure was the same as in Experiment 1 except that the participants had to decide as quickly as possible whether any given picture referred to an object that was ''artificial'' or ''naturally occurring''. They indicated their decision by means of two push-buttons using the first two fingers of their preferred hand. The assignment of fingers to the buttons was counterbalanced across participants. A trial had the following structure: First, a ready signal (''*'') was presented for 500 ms followed by a picture. The picture remained on the screen until the participants initiated their response. The next trial began 2000 ms after the participants had initiated their response. RTs were measured from the onset of picture presentation.

Results

RTs exceeding two standard deviations above the participant and item means were discarded (1.9% of the data). RTs and errors were subjected to ANOVAs with homophone frequency as an experimental factor.

On errors, the main effect of homophone frequency was not significant (8.5 and 11.8% for HF and LF homophones, respectively), $F_1(1, 30) = 2.48$, $MSe = 0.126$; $F_2 < 1$, whereas for RTs, HF homophones took longer to categorise (1045 ms) than LF homophones (775 ms), $F_1(1, 30) = 31.92$, $MSe = 18292$; $F_2(1, 34) = 24.09$, $MSe = 25210$.

Discussion

The outcome of Experiment 2 was rather surprising. In a semantic categorisation task, the homophone effect acted in the opposite direction to that observed in Experiment 1: HF homophones took longer to categorise as ‘‘artificial’’ or ‘‘naturally occurring’’ objects than LF homophones. The difference in categorisation times can be interpreted in two ways. First, it might be argued that although the print frequency of HF homophones is higher than that of their LF counterparts, the level of conceptual familiarity is just the opposite. Second, it is possible that the LF homophonic pictures were less visually complex than the HF homophonic ones, with this difference being reflected in the categorisation times. To test the first possibility, we asked an independent group of 23 participants to rate, on a 5-point scale, their familiarity with the concept depicted by the picture for the stimuli used in Experiments 1 and 2. The procedure closely followed that described by Alario and Ferrand (1999). The participants were instructed to judge the familiarity of the concept presented by each picture on the basis of how usual or unusual the object is in their realm of experience. Familiarity was defined as ‘‘the degree to which participants judged that they came into contact with or thought about the concept’’. HF homophones were judged to be more familiar than LF homophones (3.71 vs 3.06), $F_2(1, 33) = 6.11$, $MSe = 0.610$. Thus, conceptual familiarity cannot account for the homophone effect found in Experiment 2. It is important to stress that the main effects of frequency as well as the repetition by homophone frequency interaction effects observed in Experiment 1 were still significant when conceptual familiarity scores were introduced as a covariate factor. The second possibility was tested using another independent group of 23 participants. Following the procedure described by Alario and Ferrand (1999), they were asked to rate on a 5-point scale the visual complexity of each drawing (1 = drawing very simple, 5 = drawing very complex) rather than the complexity of the object it represented. Pictures corresponding to HF homophones were not judged to be significantly less visually complex than pictures corresponding to LF homophones (2.37 vs 2.98), only a trend was observed on the visual complexity scores, $F_2(1, 33) = 3.33$, $MSe = 0.977$, $p < .08$. Also, when the same kinds of analyses as those conducted on the latency data, with the name agreement measures taken into account, were performed on the categorisation times, the same pattern of results was found. A suggestion to account for the results obtained in Experiment 2 would be that the participants were more uncertain of whether to categorise the concepts as artificial or naturally occurring objects in the case of the HF homophones than in that of the LF homophones. It is clear that we are left with no satisfactory explanation for the difference in categorisation times between HF and LF homophones. Nevertheless, and most importantly for the purposes of the present paper, if we accept the assumption that a semantic categorisation task truly indexes identification and conceptual processes (Jescheniak & Levelt, 1994; Morrison et al., 1992), then the results from Experiment 2 strongly suggest that the differences observed in the naming times between HF and LF homophones were not due solely to differences in ease of identification/conceptual processes.

Finally, it is worth noting that, if the homophone frequency effects found on the naming latencies were attributable solely to identification/conceptual processes, then it would be somewhat difficult to account for the reliable interaction found on the items between homophone frequency and production mode. It should be remembered that the frequency effect was larger in writing than in speaking (such a finding had already been observed in Bonin, Fayol, & Gombert, 1998 study). In effect, if we seek to attribute the frequency effect solely to identification/conceptual processes, then clearly such an interaction is not predicted since those processes are assumed to underlie both forms of language production. For instance, in Caramazza's (1997) model, both spoken and written production share the semantic/conceptual level (see his Fig. 3A, p. 196). What should be predicted then, is that the frequency effect would not be reliably different in size between the two production modes, contrary to what was found.

Whether or not frequency can act at the conceptual level is an issue that requires further investigation, but as far as our material is concerned, taken together, the findings strongly suggest that the frequency effects found in Experiment 1 were not rooted in the identification/conceptual processes.

GENERAL DISCUSSION

The main findings resulting from Experiments 1 and 2 can be easily summarised. Experiment 1 showed that: (1) Heterographic homophonic picture names that were of higher frequency in print than their partners took less time to initialise in both spoken and written production; (2) the homophone frequency effect was attenuated with the repetition of the pictures but still persisted even after four repetitions; and (3) the repetition of the picture names had a more beneficial effect on written than on spoken picture naming. In a semantic categorisation task, Experiment 2 revealed that HF homophones took more time to categorise than LF ones.

Taken together, the findings from Experiments 1 and 2 strongly suggest that the differences in the naming times between the two categories of homophones relate to lexical processes. In effect, given that the level of visual complexity was not significantly different for the two types of homophonic pictures, that the frequency effects remained significant when conceptual familiarity scores were introduced as a covariate factor, that the categorisation times were faster for LF homophonic targets than for HF ones, and that the frequency effect was reliably larger in writing than in speaking on the item means, the identification/conceptual levels must be ruled out as a source of the effects observed in Experiment 1. A post-lexemic interpretation of these effects has already been discarded given that the HF and LF homophones were matched on initial phonemes and letters. Therefore, by a process of elimination, given the assumption that naming words from pictures involves identification, conceptual preparation, lexicalisation, and output preparation, the lexical level remains the best candidate as the locus of these effects.

As mentioned in the introduction, frequency effects in spoken language production have often been localised at the phonological lexeme level. The most compelling evidence for a phonological lexeme locus of word frequency effects in spoken language production has been provided by a series of experiments conducted by Jescheniak and Levelt (1994). The phonological lexeme hypothesis of word frequency effects in language production as proposed by Jescheniak and Levelt (1994) claims that LF homophones inherit the frequency of their HF partners. Thus, this hypothesis clearly led us to expect that, in a standard picture naming task, LF homophone picture names would be spoken aloud as fast as their HF twins.

As far as written production is concerned, given that the evidence strongly favours the hypothesis that orthographic representations can be accessed directly from semantic representations, it was hypothesised that the locus of word frequency effects originates at the level of orthographic lexemes. We therefore expected LF homophones to be written more slowly than HF homophones. Taken overall, our findings are at variance with the phonological lexemic hypothesis of word frequency effects in spoken production as advanced by Jescheniak and Levelt (1994), but they are compatible both with the hypothesis, which derives from one-lexical level models, that there exist separate phonological lexemes for any given pair of homophones, and with the hypothesis that frequency effects are encoded in the links between semantic representations and lexeme representations (Barry et al., 1997; McCann & Besner, 1987; Wheeldon & Monsell, 1992). It is worth noting, however, that Caramazza and Miozzo (1998) have recently claimed that the findings of Jescheniak and Levelt (1994) concerning homophone processing are not problematic for models with only one lexical level that represents homophones as independent lexical entries, provided that interactivity between the phonological lexeme and the segmental levels is permitted. However, this interpretation comes with a caveat: If it took the form of a feedback from the segmental level to the phonological lexeme level, we should have observed LF homophones being processed at the same speed as HF homophones in spoken production. But this explanation is not supported by the present empirical findings.

It is important to stress that we used *heterographic* homophonic picture names in our experiments, whereas Jescheniak and Levelt (1994) used *homographic* homophonic words (p. 836 of their paper). Might this latter difference be responsible for this discrepancy? To attempt a tentative exploration of this question, we take as our basis certain findings and interpretations reported by Wheeldon and Monsell (1992) in a study of repetition priming effects in spoken picture naming. These researchers found that the production of heterographic homophones in response to definitions did not facilitate the subsequent production of the same phonological forms in a picture naming task using pictures that depicted concepts other than those activated by the definitions. In contrast, they found that there was a modest facilitatory effect of homophone priming, albeit non-significant, on the spoken naming latencies when the primes and targets were spelled the same, i.e., *ball*. Wheeldon and Monsell (1992) discussed the following possibility in order to account for their findings. It could be that during spoken word production, orthographic codes are automatically activated in parallel with phonological codes (for evidence of automatic activation of orthographic codes during spoken word recognition see Donnenworth-Nolan, Tannenhaus, & Seidenberg, 1981; Jakimik, Cole, & Rudnicky, 1985; Seidenberg & Tannenhaus, 1979; Ziegler & Ferrand, 1998). If the activated orthographic representation reactivates its associated meaning then different orthographic representations will be retrieved during the production of heterographic homophones, e.g., *wait/weight*: The orthographic representation activated during the production of *weight* should not activate the meaning of *wait*. However, in the production of homographic homophones, e.g., *ball*, the same orthographic representation will be retrieved and both meanings of *ball* will be activated. Such a feedback loop of reciprocal activation from meaning to phonology and back to meaning might also be involved but only after a sufficient activation has accumulated at the phonological level to trigger later processes. According to Wheeldon and Monsell (1992), it is only because the latencies of the orthographic loop and phonological loop are to some degree uncorrelated that the effects of the orthographic loop may sometimes have an effect before successful phonological activation is achieved. Thus, the difference between Jescheniak and Levelt's (1994) findings and ours might be related to the use of different types of homophones—homographic versus heterographic—and to the existence of a feedback loop from orthographic and phonological lexemes to semantic representations. Because of this feedback loop between orthographic lexeme representations, LF homographic homophones would be processed as fast as HF ones. To illustrate this point, let us consider the example of the homographic homophone *ball* which can refer to either a formal dance or a toy. The sequence of events would run as follows. The meaning of *ball* (dance) is activated from a picture and sends activation to both the orthographic lexeme *ball* and the phonological lexeme /bol/. The orthographic lexeme *ball* sends activation back to the conceptual level and (re)activates the meaning ''*dance*'' but also activates the meaning ''*toy*''. In turn, the activated meanings activate the phonological lexeme /bol/. The consequence is that the phonological lexeme /bol/ attains a higher activation level than in a situation in which the phonological lexeme is activated only from its associated meaning. In the case of a heterographic homophone, such as *wait*, the orthographic feedback loop reactivates the meaning ''*wait*'' but does not activate the meaning ''*weight*''. Thus, the phonological lexeme *wait* receives activation back only from the intended meaning. Of course, for this interpretation to be correct, it has to be accepted, as in Wheeldon and Monsell (1992), that such a feedback loop of reciprocal activation from meaning to phonology and back to meaning might also come into play but only after sufficient activation has accumulated at the phonological level to trigger later processes. The time course of activation of the feedback loop from orthography to meaning might be dependent on the frequency of the orthographic lexeme. Therefore, the different time course of activation of this latter feedback loop as a function of the frequency of orthographic lexemes would account for the homophone frequency effects observed for heterographic homophones. We acknowledge that this interpretation is speculative. But it seems that in order to provide a full account of the lexical processing of heterographic and homographic homophones, interactivity in lexical access production models is a necessary processing assumption (see Cutting & Ferreira, 1999; Rapp & Goldrick, 2000, for related evidence). Clearly, the potential difference in the processing of homographic and heterographic homophones that has been identified requires further investigation. Alternatively, it might simply be that Jescheniak and Levelt (1994) were wrong.

Undoubtedly, our findings cast some serious doubts on the phonological lexemic hypothesis of word frequency effects in spoken language production as put forward by Jescheniak and Levelt (1994) and, onwards, impose further constraints on the modelling of access to spoken and written name representations.

A final point that will be briefly addressed relates to a debate surrounding frequency effects in language production. It has been argued that frequency effects in language production might merely be age of acquisition (AoA) effects in disguise (Morrison et al., 1992). AoA effects refer to the finding that words acquired early in life (EA words) are retrieved faster from memory than words acquired later (LA words) and, more specifically, as far as spoken production is concerned, that EA words are produced faster and more accurately than LA words (Barry et al., 1997; Carroll & White, 1973; Hodgson & Ellis, 1998; Lachman, 1973; Lachman et al., 1974; Morrison et al., 1992, 1997). Some authors have strongly claimed that studies that have investigated frequency effects have failed to control for AoA, so that putative frequency effects might actually be genuine AoA effects (Morrison et al., 1992). In some spoken picture naming studies, it has been found that when AoA scores were taken into account in multiple regression analyses, AoA but not word frequency was a significant independent determinant of naming latency (Carroll & White, 1973; Gilhooly & Gilhooly, 1979; Morrison et al., 1992; but see Barry et al., 1997; Snodgrass & Yuditsky, 1996). As far as written production is concerned, Bonin et al. (2001) recently found that AoA affected object naming speed when objective word frequency was controlled for, whereas objective word frequency did not significantly affect written picture naming performance when AoA was controlled for (for similar findings in spoken production see Barry, Hirsh, Johnston, & Williams, 2001). In our experiments, AoA was not controlled for. To assess whether word frequency was indeed confounded with AoA, we asked an independent group of 20 participants to rate the items used in Experiments 1 and 2 for AoA on a 5-point scale. The procedure followed that described by Alario and Ferrand (1999). This normative study revealed that HF homophones were estimated as being acquired more early in life than LF homophones (2.07 vs 3.03), $F_2(1, 34) = 14.27$, $MSe = 0.582$. Given these results, we acknowledge that our frequency contrast was also an AoA contrast. A regression analysis was performed on the item means of both spoken and written naming latencies with word frequency (log transformed) and AoA as predictor variables. In spoken production, AoA was a significant determinant of naming latencies whereas word frequency was only marginally significant ($p < .08$). In written production, both AoA and word frequency were significant predictors of naming latencies.

It must be stressed that our study was not designed to address the AoA issue in language production and to determine whether AoA or word frequency is the key variable, although we acknowledge that this is clearly an issue that future research will have to address. The confound of word frequency with AoA (which was also present in the Jescheniak and Levelt, 1994, study; see Barry et al., 1997) does not undermine the purpose of the present study because, as we noted in footnote 1, the theoretical accounts of word frequency and AoA in word production are in some regards similar in terms of the models that are considered in the paper. For instance, Levelt et al. (1999) have explicitly claimed that word frequency and AoA effects can be modelled in exactly the same way: ''we will assume that they affect the same processing step, that is, accessing the word form. Hence, in our theory, they can be modelled in exactly the same way, either as activation thresholds or as verification times'' (p. 19).

However, to some extent, our findings also enable us to address the AoA issue because AoA effects in speaking have also been located at the phonological lexeme level. To explain the emergence of AoA effects, one commonly held explanation has been that the representations of EA words are more unitary and more complete than those of LA words. Nevertheless, this explanation, referred to as the completeness hypothesis (Brown & Watson, 1987; Gilhooly & Watson, 1981), as yet lacks clear empirical support. If it is assumed that homophones share their phonological lexeme representation, then the completeness hypothesis holds that the speed at which homophones are produced in speaking should be determined by the age at which the phonological form of the first member of a homophone pair is acquired. Therefore, homophonic members should be spoken aloud at the same speed. Again, our findings are clearly at variance with such an account of AoA effects in spoken language production.

To conclude, although our findings are useful in that they add further constraints to the modelling of word frequency effects (and, to some extent, AoA effects) in language production, it is obvious that more intensive research is needed to determine in greater detail the impact of word frequency and AoA and their relations in conceptually driven naming tasks as well as the mechanisms that give rise to these effects.

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APPENDIX: MATERIAL FROM EXPERIMENTS 1 AND 2

The approximate English translation is given in parenthesis and naming latencies (in ms) for the spoken and written production in Experiment 1.

	Spoken production				Written production			
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*
HF homophones								
Lait (milk)	785	689	693	647	1166	943	886	865
Reine (queen)	720	649	651	606	1032	959	844	926
Lutte (wrestling)	702	654	625	641	1135	991	880	814
Mur (wall)	858	634	612	619	1131	1022	857	816
Canne (cane)	647	640	600	627	983	919	809	862
Lac (lake)	738	648	644	628	1071	885	936	830
Col (collar)	716	677	616	624	1071	887	894	878
Verre (glass)	644	662	600	629	1050	878	822	828
Encre (ink)	761	690	639	637	1055	977	925	905
Poids (weight)	770	731	676	701	1095	998	985	886
Corps (body)	770	722	681	727	1212	954	943	913
Signe (sign)	887	815	785	779	1167	1009	927	825
Coq (rooster)	733	670	647	644	1054	895	855	831
Balle (ball)	656	660	655	615	1048	953	881	835
Cæur (heart)	622	616	602	612	963	819	829	847
Chêne (oak)	880	751	701	700	1154	991	893	861
Point (point)	833	777	742	703	1122	1017	886	897
Cent (hundred)	668	667	656	622	1067	857	821	883
LF homophones								
Laie (wild sow)	1078	826	751	732	1256	1097	984	1000
Renne (reindeer)	1053	824	746	743	1548	1156	1018	1031
Luth (lute)	1064	852	801	729	1754	1315	1164	1084
Mûre (blackberry)	798	680	689	657	1208	1052	956	968
Cane (duck)	996	811	876	938	1325	1160	1068	1043
Laque (hair spray)	844	747	700	680	1394	1079	1083	1060
Colle (glue)	952	766	714	727	1254	1076	1047	962
Ver (worm)	843	733	757	692	1372	1001	1134	1092
Ancre (anchor)	816	764	694	693	1193	1160	999	974
Pois (pea)	902	727	686	678	1188	1012	1023	947
Cor (horn)	966	829	762	721	1592	1145	987	971
Cygne (swan)	1055	985	820	787	1278	1072	1124	991
Coque (hull)	973	780	771	711	1242	1046	970	979
Bal (ball)	849	764	715	720	1517	1070	1016	1063
Chæur (chorus)	977	910	845	785	1207	1112	1012	989
Chaîne (chain)	872	765	756	693	1122	1071	950	944
Poing (fist)	727	659	645	650	1124	1106	934	1045
Sang (blood)	906	809	788	768	1145	1251	1012	968

HF = high frequency, LF = low frequency; 1 = first presentation of the pictures, 2 = second presentation, 3 = third presentation, 4 = fourth presentation.